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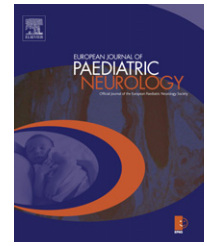

Original article

The effect of individually defined physiotherapy in children with cerebral palsy (CP)

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ABSTRACT

Aim: This prospective double blind intervention study aims to evaluate the effectiveness of an individually defined physiotherapy program on the function and gait pattern of 16 children with diplegia (age 3–12 year, GMFCS I–II).

Method: A 6 weeks general training program was followed by a specific training program based on individual goals determined by the results of 3D gait analyses, GMFM-88 and a clinical evaluation. Goal attainment scores were used for the evaluation of the achievement of individual goals.

Results: After the general training program, 6.7% of the children achieved the treatment goals, 33.3% stayed at the same level and 60% worsened and this in comparison to 40, 33.3 and 26.6% of the children respectively after the individually defined training program. The improvement for walking, running and jumping of the GMFM-88 was significantly more pronounced after the individually defined ($p < 0.05$), compared to the general training program. Whereas ankle dorsiflexion, spasticity of the hamstrings ($p < 0.01$), selectivity of hip abductors, knee extensors and ankle dorsiflexors significantly improved over the complete period of study ($p < 0.01$), hip extension, step length, stride length, ankle power generation and all hip parameters changed specifically after the individually defined training program ($p < 0.01$).

Conclusion: A quantified effect is manifest with the application of an individually defined training program over a six weeks period.

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1. Introduction

Cerebral palsy (CP) is one of the most common causes of motor disability in childhood. CP describes a group of disorders of movement and posture, causing activity limitation and is attributed to non-progressive disturbances occurring in the developing fetal or infant brain. Abnormal motor behavior is the core feature of CP.[1] In clinical practice, the majority of children diagnosed with cerebral palsy follow a physiotherapy training program. The influence of physical therapy is not

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easy to evaluate because there are many inherent difficulties. Researchers face inevitable methodological problems and practical constraints, such as small and heterogeneous samples, non-random assignment into groups, lack of a control non-treatment group and inappropriate outcome measures. Studies of the effectiveness of physical therapy have reported conflicting or inconsistent findings.[2–10] A high-quality reviews found evidence supporting strength training, constraint-induced movement therapy and hippotherapy.[11]

Setting goals and evaluating them are essential steps in physical therapy intervention.[12] Physiotherapists often identify a set of general aims in relation to the treatment of their patients, such as improvement of trunk balance or gait pattern. While such aims reflect the general direction of changes in the patient's performance they do not define the achievement with any measurable precision.[13] Setting a treatment goal involves identifying and formulating standards of motor activity which are in advance of the child's current capacity or which retard deterioration.[14] Previous studies on a group of quadriplegic children reported improved motor function after treatment using precise goal setting.[15,16] However, the results of this study also reflected the effects of an increased frequency in therapy and this over a short time period. A follow-up study evaluating the long-term effects could not confirm these effects.[17]

Furthermore when general aims are identified, researchers often make use of a general training program. This may make it even more difficult to find evidence. In a recent review article, Papavasiliou notes the shift of traditional physiotherapy approaches to goal oriented approaches but mentions the insufficient reporting of trials.[18]

Aim of this study is to evaluate the effectiveness of an individually defined physiotherapy program and to overcome the majority of the above-mentioned problems, thereby contributing to the insight into the evidence of physiotherapy.

2. Materials and methods

Sixteen children with spastic diplegia ranging in age from 3 years 10 months to 12 years 1 month (X = six years four months, SD two years five months) were selected. Inclusion criteria were: walking without assistive devices, appropriate use of orthoses, co-operation for assessment and a regular routine in physiotherapy treatment before inclusion in the study. Children with muscle contractures or bony deformities, multi-level surgery less than one year prior to the intake of the study or Botulinum Toxin A (BTX-A) within the previous six months were excluded. One child did not finish the study because of an unexpected treatment with BTX-A. Thirteen children were born prematurely. The study was approved by the Ethics Committee of the University College Arteveldehogeschool.

To evaluate the effect of different physiotherapy interventions, a double blind repeated measures design was used and is presented in Fig. 1. A baseline evaluation was followed by a six weeks general training program. The effects of this training period were evaluated during a period of 4 weeks of usual physiotherapy. A second training period was implemented for another 6 weeks in which the children received an individually defined training program. All children were re-evaluated after this training program.

Both the general and the individually defined training program were given by the child's usual physiotherapist. Twelve physiotherapists participated in the study. All physiotherapists were certified physiotherapists, specialized in paediatric rehabilitation. All physiotherapists were informed in advance on the principles of the study but were blinded to the type of program and the individually defined treatment goals. To re-assure the double-blind design, the therapists following two children in the study, received two slightly different general programs. The content of the programs, however, was strictly defined by a senior paediatric physiotherapy instructor. Participating physiotherapists were only given a detailed list of exercises.

The general program was the same for all children and was not specifically adapted to the child's individual problems. It consisted of non-specific exercises, including stretching and mobilization (20% of the time), muscle strengthening (40% of the time) and functional exercises (40% of the time). For all children, stretching was performed on m. Iliopsoas, hamstrings and m. Gastrocnemius. M. Gluteus maximus, m. Gluteus medius, and m. Quadriceps femoris were strengthened. The functional exercises were focused on the stability of the pelvis, balance and walking. Each child received three sessions of physiotherapy of 60 min a week. Table 1 describes the contents of an example of a general program.

The individually defined training program was based on the results of the gait analysis and clinical examination. The senior NDT physiotherapy instructor defined three main problems. The main problems of the child were translated as specific goal settings to set up the individually defined training program. In this way, for each child, a specific 'tailor made' program was designed. The most frequently used treatment goals were knee extension at initial contact, reduction of the pathological plantar-flexion knee extension couple and lateral stability of the pelvis. An example of the design of an individually defined program is given in Table 2.

Frequency of physiotherapy, the reasons of absence and the difficulties during therapy were recorded in a diary. Therapy adherence could thereby be evaluated. Three categories were made: very regular visits to the therapist (more than 85% of the sessions prescribed were followed), less regular visits to the therapist (75–85% of the sessions prescribed were followed) and no regular visits to the therapist (less than 75% of the sessions prescribed were followed).

Evaluations included 3D objective gait analysis, a standardized clinical examination and GMFM-88. All evaluations were performed by an independent and experienced assessor (physiotherapist or kinesiologist), working at the Laboratory of Clinical Movement Analysis. The assessors were blinded to the treatment type.

During gait analysis, time and distance parameters, kinematics and kinetics were collected by an eight camera VICON system and two ATMI force plates. Workstation and Polygon software were used to collect and process the raw data. The kinematic report included joint angles in the three anatomical planes (hip, knee and ankle) and orientation of the pelvis and foot. The force plate data yielded vertical, vent/dorsal and medial/lateral reaction forces, from which the resultant ground

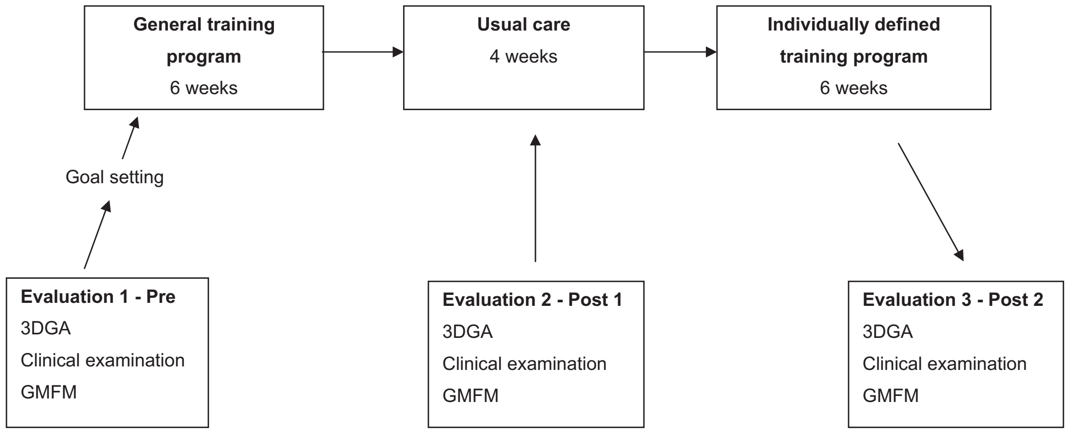


Fig. 1 – Study design.

reaction force and application point under the foot were calculated. Combined with anthropometric and kinetic data, the net joint moments and power were calculated. Surface EMG of m. Tibialis anterior, m. Soleus, m. Gastrocnemius, medial and lateral hamstrings, m. Rectus femoris, m. Vastus lateralis and m. Gluteus medius was collected bilaterally.

Within the clinical evaluation anthropometric data (weight, height, bicondylar femur, bimalleolar and leg length) were collected. The passive range of motion of the hip, knee and ankle was measured. Spasticity in the lower extremity was evaluated according to the Modified Ashworth Scale (MAS) of Spasticity, the Modified Tardieu Scale (MTS), the Duncan Ely test and the ankle clonus test. Also the strength (Manual Muscle Testing) and selective control[19] of different muscles of the lower extremity were measured. A sum of scores was made for the measures of strength and selective control. Clinical examination also included a functional evaluation: hip extension was evaluated during walking and standing on one foot. Evaluation of pelvic control was made in stance on both legs and while standing on one foot.

Table 1 – The general training program.

Aim	Position	Repetitions
Stretching hamstrings and m. Gastrocnemius	Long sitting	20
	Standing	
Pelvic control		
hip extension (bridging)	Supine, knee extension with hip adduction	3 × 20
hip extension (briding)	Supine, knee extension with hip abduction	3 × 20
sidewards sitting	Knee-standing	2 × 20
trunk rotation	Prone lying, hips extended, thighs on bal	5 × 10
pelvis anteversion/retroversion	Hands & knees	20
Mobilization of the hip	Prone, hips extended, knees flexed	2 × 20
Strengthening plantar flexor muscles	Toe standing, knees extended	3 × 20
Strengthening m. Obliquus abdominis	Supine, rolling against resistance	2 × 10
Strengthening knee extensors	Supine, knee extension	5 × 10
	Standing against the wall, squatting	3 × 10
Strengthening m. Glut Max	Prone lying, hip extension	2 × 20
Sit-to-stand	Sitting	20
Standing balance		
anteroposterior direction	Standing, feet closed (throwing & catching balls)	20
	Standing, hips abducted (idem)	20
lateral	Standing, feet together (resistance against pelvis)	20
one leg standing	One leg standing	20
Gait training		
sidewards walking	Sidewards walking against a wall	20 steps
backwards walking	Backwards walking	20 steps
pelvic control	Shoulders externally rotated, walking between lines	20 steps
Jumping		
forwards	Standing, feet closed	5
backwards	Standing, feet closed	5
sidewards	Standing, feet closed	5

Note: Column 1 (aim) was not given to the physiotherapists.

Table 2 – Example of an individually defined training program.

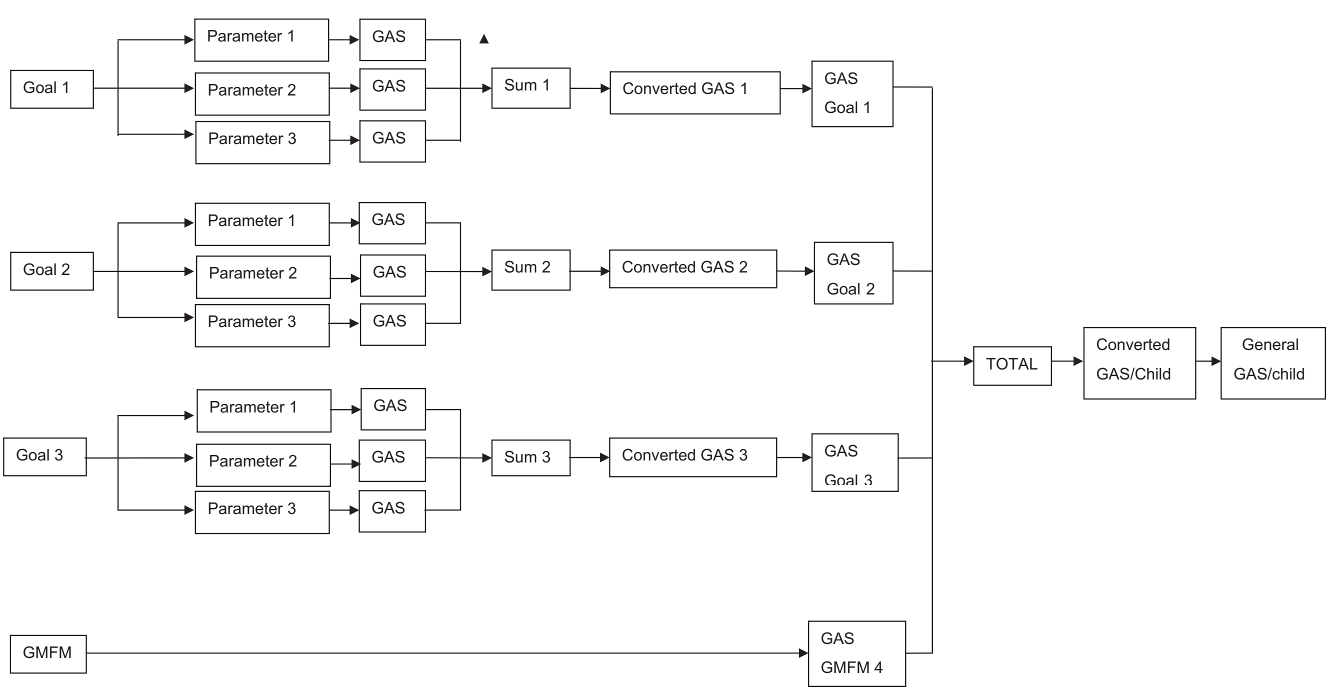
	Position	Repetitions
Goal 1: Improving frontal and transversal pelvic stability		
Subgoal 1: Stretching m. Psoas	Prone lying, knees flexed	20 × 5 s
Subgoal 2: Active hip extension	Prone lying, knees flexed, leg lift	20 × 5
Subgoal 3: Strengthening m. Obliquus abdominis	Supine, pelvic rotation	20×
Subgoal 4: Active dissociation trunk and pelvis	Long sitting, hips abducted, knees extended (ball games)	20×
	Standing, hips and knees extended (ball games)	5 min
Subgoal 5: Pelvic stability in stance	One leg standing, one leg on thigh therapist	5 min
	One leg standing, one leg moving backwards and forwards	5 min
	Sidewards walking	5 min
Goal 2: Improving hip extension		
Subgoal 1: Stretching m. Psoas	Prone lying, knees flexed, hip extension	20 × 5 s
Subgoal 2: Active hip extension	Prone lying, knees flexed, hip extension	20 × 5
Subgoal 3: Extension during walking	Backwards walking, guided full hip extension	5 min
Goal 3: Improving knee flexion at initial contact		
Subgoal 1: Stretching hamstrings	Long sitting, knees in extension	20 × 5 s
Subgoal 2: Active knee extension (strength m. Quadriceps femoris)	Long sitting, knees in full extension	20 × 3 s
Subgoal 3: Active knee extension in stance	Standing, moving leg forwards with full knee extension	5 min

Note: Column 1 (goals) was not given to the physiotherapists.

Gross motor ability was assessed using the GMFM-88. Dimensions C (crawling and kneeling), D (standing) and E (walking, running and jumping) were used for further analysis.

For the majority of continuous and categorical variables, the distribution was tested as not normal. Consequently, the median (Me) and inter-quartile range (IQR) was calculated. For the categorical variables with a small number of classes a frequency distribution was made. A Friedman test and post-hoc Wilcoxon signed rank test were used to evaluate the differences between the different evaluations. Because of the Bonferroni correction for the repeated evaluations, the critical p-value of the Wilcoxon signed rank test was determined at <0.01.

Treatment success was defined by Goal Attainment Scaling (GAS). GAS is an individualized criterion referenced measurement that quantifies the achievement of treatment or intervention goals for different kinds of treatment issues.[20,21] During the present study (Fig. 2), three or four goals were identified for each child, including a number of gait and clinical evaluation goals and dimension E of the GMFM-88. For each gait and clinical evaluation goal, one to five parameters of the gait cycle that could measure the outcome of the goal in an objective way, were selected and each parameter was scored between −2 and 2. A GAS-0 indicated an improvement of 30% of the pathology. A GAS-1 indicated that there was no



Note: Example of the data analysis for a child with 3 goals and the additional GMFM goal with 3 parameters per goal

Fig. 2 – Data-analysis for the Goal Attainment Scale (GAS).

difference. GAS-2 was an increase of pathology. GAS-1 was defined as a correction of 30–50% correction of pathology. GAS-2 was a normalization or more than 50% correction of pathology. For each goal, the GAS scores of the parameters were summed and converted into a converted GAS score for each goal. The converted GAS was again reconverted into a GAS per goal. For each child, the GAS scores of each goal were summed and converted into a general converted GAS. This resulted in a score between 0 and 100. The total group mean, standard deviation, median and inter-quartile range of the total group was defined. To obtain a general GAS per child, the converted GAS was reconverted into a score with range −2 to 2. The frequency of attaining the goals and a Wilcoxon signed rank test was done on the general GAS scores.

3. Results

Step length, stride length, cadence and gait velocity improved significantly after the individually defined training program.

Ankle velocity around toe off, ankle power generation at pre-swing, maximum knee extension in stance, maximum knee velocity, maximum knee extension moment and all hip parameters changed significantly after the individually defined training program. For gait analysis only the clinically relevant parameters will be reported.

In the clinical examination, only ROM of hip extension and ankle dorsiflexion with the knee in 90° changed significantly. There was a significant ($p < 0.01$) increase in passive hip extension between the second and third evaluation. Ankle dorsiflexion changed significantly over the entire period of the study. Spasticity of the hamstrings, selective motor control, strength of the hip abductors, selectivity of the hip abductors, sum score of strength and selectivity of the hip abductors, selectivity of the knee extensors, selectivity of the dorsiflexors with knee in 0° and the sum of score of strength and selectivity of the dorsiflexors with knee in 0° increased significantly over the period of the study.

The clinical evaluation revealed significant changes ($p < 0.01$) for the parameters stance on one foot with resistance forwards, stance on one foot with resistance backwards and stance on one foot with resistance to the left.

The total score of the GMFM-88 showed a tendency of increasing during the periods between the three evaluations. The median of the total % score of the GMFM-88 was 94% at the beginning of the study, 88% after the general training program and 96% after the individual defined training program. This increase was not found significant.

The median of dimension crawling and kneeling (dimension C) was 100% at the three evaluation points which is the maximum score on this dimension.

The median of standing (dimension D) was 90% at the beginning of the study, 92% after the general training period and 95% after the individual defined training program. This increase was also not found significant.

The score on walking, running and jumping (dimension E) increased significantly ($p < 0.01$), both after the general training period and the individual defined training program. The median of dimension E was 76% at the beginning of the study, 79% after the general training period and 88% after the individual defined training program. The increase was significantly ($p < 0.05$) more pronounced after the individual defined training program (Fig. 3).

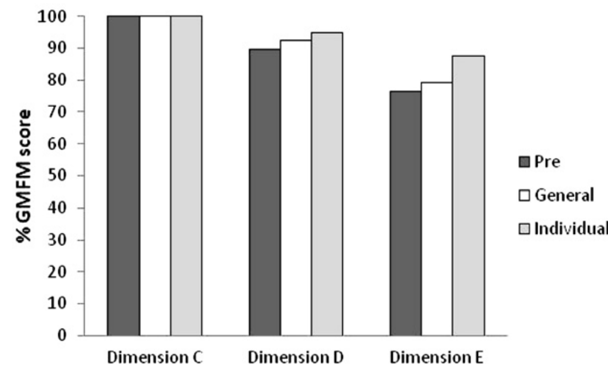


Fig. 3 – Median of dimension C (crawling and kneeling), dimension D (standing), dimension E (walking, running and jumping) and total GMFM score.

The median of the standardized general GAS score measured between the baseline and the third evaluation was 41. The median measured between the baseline and the second evaluation was 35 and the median between the second and third evaluation was 42. The median of the standardized general GAS score per child measured after the general training program differed significantly ($p < 0.01$) from the median of the standardized general GAS score measured after the individually defined training.

The general GAS per child showed that after the general training program, 6.7% achieved the goal of the treatment, 33.3% stayed at the same level and 60% worsened. After the individually defined training program, there were 40% of the children who achieved the goal of treatment, 33.3% stayed the same and 26.6% worsened. Fig. 4 shows the frequencies of individual general GAS scores per child after the general and the individually defined training program.

There was no significant correlation between therapy adherence and the general GAS score per child after the individually defined training program.

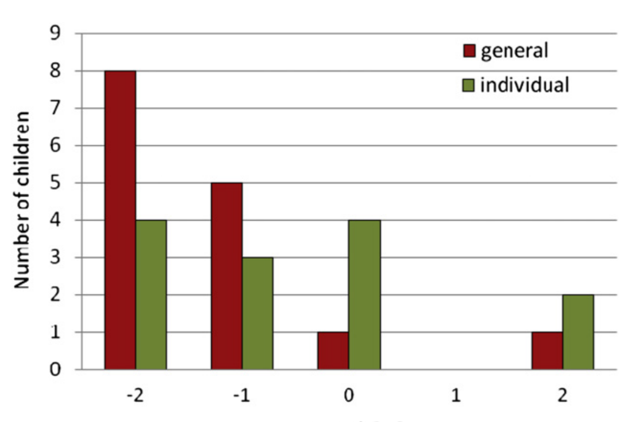


Fig. 4 – Frequencies of individual general GAS scores per child after the general training program and the individually defined training program.

4. Discussion

There is still a little evidence about the effectiveness of physiotherapy in children with cerebral palsy. As mentioned earlier in this paper, high-quality reviews found some evidence supporting strength training, constraint-induced movement therapy or hippotherapy and insufficient evidence on comprehensive physiotherapy and occupational therapy interventions. Conclusions in other reviews should be interpreted cautiously.[11] Hur[2] reviewed 37 studies of therapeutic interventions for children with cerebral palsy. Of seven studies using a comparative design, only two studies showed a significant treatment effect. Mayston[3] found that there is an evidence that therapy can improve functional possibilities, but is inconclusive which approach might be most beneficial. The small samples sizes (calling into question the power of the studies), considerable heterogeneity of participants as well as variance in therapy treatment across time and across therapists and the influence of external factors make this research challenging and complex.

Also in this study, several methodological difficulties could not be overcome. The sample size of 16 children was relatively small. However, a larger group would make follow-up less realistic and manageable. Nevertheless, in spite of the small sample size, statistical significance was reached. A smaller number of sample size however, usually hampers statistical significance. Reaching statistical significance using a small sample size however, obviously reflects the outspoken training effects throughout the different training programs.

The sequence of intervention could not be randomized. Instead, all children underwent both interventions and functioned as their own control. Additionally, ethical constraints limited the possibilities to use a control non-treatment group.

The gait parameters cadence and stride length increased significantly. Cadence and normalized velocity correlate very strong with the GMFM-88. Cadence accounts for 60% of the variance in GMFM-88 score. Stride length, hip and knee excursion and single support also show a significant correlation with the GMFM-88 score.[22] After an individually defined training program a significant increase in dimension E of the GMFM-88 was found. Step length, stride length, cadence and gait velocity changed significantly. It appeared that 86.7% of children had a progression or a stabilization in their performance.

The overall goal of any therapy is to improve function. The GMFM-88 is a clinical measure designed to evaluate change in gross motor function in children with cerebral palsy. The GMFM has excellent inter-rater agreement scores, with very high ICC scores, varying amongst the different dimensions from 0.87 to 0.90.[28–30] Positive effects of a training period on the GMFM-88 have been described before.[6,9,10,14,16] However, GMFM-88 has some limitations: overall improvement on the GMFM-88 requires acquisition of a new motor skill[17] and is not sensitive enough to detect small improvements. Floor and ceiling effects can influence the sensitivity of the GMFM-88.[23] For example in the present study, the median of item crawling and kneeling (dimension C) was 100% at the three evaluation points which is the maximum score on this item. Four children did not improve on item E because these children had high results at the baseline on this item. The three oldest children did not improve their GMFM-88 score.

Clinical assessment was performed by an experienced physiotherapist working at the clinical laboratory of motion analysis, specifically trained for objective evaluations but blinded to the training programs of the participants. ROM was measured using standard goniometry, were reliability was found moderate. The standard error (SE) of measurement was respected in the definition of clinical measurable change.[24,25] For spasticity assessment, both MAS and MTS were used.[26,27] Although several authors comment on the reliability and validity of the MAS, combination of both measurements is used to increase evidence of clinical change in spasticity.[31] Where MAS measures mainly passive resistance to motion, MTS reflects heightened stretch responses.[27] Additionally specific attention is given to standardization of testing and the use of experienced, trained assessors only. The inter-rater reliability studies performed at the Clinical Motion Analysis Laboratory showed a moderately high to very high inter-rater reliability (0.60–0.91).[32] Muscle strength was measured using the Oxford Manual Muscle Testing Scale and selectivity was measured on a 5 point scale, all in standardized patient positioning. Clinical assessment was only one part of the total assessment. Outcome measurements were used in a repeated measurement analysis but also in the definition of certain goals defined for goals-attainment scoring. All clinical parameters show a similar tendency of improvement after the individually defined training program, supporting our hypothesis that an individually defined training program could be more beneficial for children with cerebral palsy.

When the general training program is compared to the individually defined training program, some similarity in the exercises can be found. However exercises in the individually defined training program were more functional: strengthening was done in a more functional setting and the muscles were trained in a more specific part of the range of motion. They focused on improving gait (walking forward, backward and to the side). The study design can be improved by making the general training even more general, not focusing on any functional improvement and by informing the therapist about the treatment goals.

The results give an indication that an individually defined training program provides better functional results than a general training program. The GMFM-88 improved more after the individually defined training program in comparison to the general training program. After the individually defined training program several parameters of the clinical examination and gait analysis changed significantly. Although statistical significance might sometimes be ‘borderline’, the number of parameters that change significantly after the individually defined program demonstrate an obvious trend towards the preference of an individually defined, goal-oriented treatment program. These results are clinically relevant for all physiotherapists working with children with CP.

Taking into account the nature of the objectives and the outcome, it can be concluded that a quantified effect is manifest with the application of an individually defined training program over a six weeks period.

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